05142 Abstracts Collection
Disruption Tolerant Networking
— Dagstuhl Seminar —

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Abstract. From 03.04.05 to 06.04.05, the Dagstuhl Seminar 05142 "Disruption Tolerant Networking" was held in the International Conference and Research Center (IBFI), Schloss Dagstuhl. During the seminar, several participants presented their current research, and ongoing work and open problems were discussed. Abstracts of the presentations given during the seminar as well as abstracts of seminar results and ideas are put together in this paper. The first section describes the seminar topics and goals in general. Links to extended abstracts or full papers are provided, if available.

Keywords. Mobile networking, disconnected operation, delay-tolerant networking, internet protocols, transport protocols, ad-hoc networking, intermittent connectivity

05142 Executive Summary – Disruption Tolerant Networking

Disruption Tolerant Networking (DTN) is a new area of research to improve network communication when connectivity is periodic, intermittent, and/or prone to disruptions. A seminar on DTN was held at at Schloss Dagstuhl, Germany, from 3 to 6 April 2005. Researchers from different fields discussed their approaches to dealing with delays, intermittent connectivity, and the potential non-existence of an end-to-end path in a number of different environments. The two major areas identified were: (1) dealing with delay and disruption in the present Internet in the context of wireless, mobile, and nomadic communications, supporting existing applications and (2) addressing new applications with a focus on exploiting discontinuous connectivity and opportunistic contacts for asynchronous communications. This article briefly reviews the seminar presentations and discussions.

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Disruption Tolerant Networking
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Keywords: Delay-tolerant networking, disconnected operation, mobility, ad-hoc networks, sensor networks, interplanetary Internet

Joint work of: Brunner, Marcus; Eggert, Lars; Fall, Kevin; Ott, Jörg; Wolf, Lars

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2005/350

Some thoughts on Disruption Tolerant Networking for asynchronous networking applications

Bengt Ahlgren (SICS - Kista, S)

The mobile user is facing many options for wireless access with highly varying characteristics, including shorter and longer disconnection periods. We argue that three components are needed to enable efficient use of available accesses. (1) An agent that helps the user choose access considering cost, performance, application need and user preferences. (2) Applications which are network aware. (3) Scheduled communication which takes advantage of prediction of future access opportunities. We illustrate the ideas with a train commute scenario and a digital camera scenario where pictures are sent to a home storage. For the latter, we argue that a storage service rather than a bundle communication service is a useful abstraction.

Joint work of: Ahlgren, Bengt; Grönvall, Björn

An Optimized TCP for Internet Access of Vehicular Ad Hoc Networks

Marc Bechler (TU Braunschweig, D)

Communication issues in vehicular ad hoc networks typically address aspects of link layer and network layer. These layers are basically enough to provide vehicular applications. The Internet integration of vehicular ad hoc networks additionally has to address transport layer issues: Typically, a proxy-based approach is used to bring together the Internet and the vehicular ad hoc network. In general, the proxy allows us to deploy a highly optimized transport protocol. Although this approach sounds evident in theory, it is practically (and economically) not feasible since the deployment of existing IP-based applications in the vehicular ad hoc network requires additional implementation to adapt them to the new transport protocol services. We therefore propose and discuss an optimized TCP the Internet access of vehicular ad hoc networks. This transport protocol has to deal with both temporary disconnection from the Internet caused by either the absence of gateways or by disruptions in the ad hoc network. It

therefore leverages information from underlying communication protocols (e.g. ad hoc routing protocol and mobility management protocol) and is able to react very quickly to temporary disconnections and transmission errors. We will also discuss the results of measurements achieved in an emulation environment.

Keywords: Transport Layer, Ad Hoc Networking, Delay Tolerant Networking

Joint work of: Bechler, Marc; Wolf, Lars

Disruption Tolerance: The Near End

Carsten Bormann (Universität Bremen, D)

Disruption Tolerance: The Near End

Carsten Bormann <cabo@tzi.de> Dirk Kutscher <dku@tzi.de> Jörg Ott <jo@netlab.hut.fi>

Today's mobile Internet users are likely to concur with a need to add a measure of disruption tolerance to the applications they use every day.

In order to facilitate deployment, this should involve little new infrastructure and no roll-out of new applications.

Apart from certain improvements at the link, network and transport layers, it is necessary to consider the application layer.

Currently, many application protocols bind their context to transport connections that may be fragile in the presence of disruptions.

Other application layer protocols issues may prevent the initiation of additional transactions when a longer one is blocked for the network.

Several application layer protocols are discussed, leading to conclusions about design guidelines for disruption-aware application protocols.

Keywords: Disruption tolerance, application layer, session context, mobile users, disruption-aware application protocols

Joint work of: Bormann, Carsten; Kutscher, Dirk; Ott, Jörg

Disruption Tolerant WWAN Media Streaming

Julian Chesterfield (Cambridge University, GB)

We consider the forms of disruption experienced by a mobile node in the cellular wide area network environment, presenting techniques to overcome both signal degradation as a result of interference from external sources and loss of service due to mobility and base station handover or loss of signal range.

Our experiments have demonstrated that utilising link level reliability in cellular networks is not practical for interactive multimedia streaming since the variation in packet propagation latency is on the order of 100s of milliseconds. By disabling reliability therefore we can bound the jitter however we experience a

high level of loss due to signal errors. We have developed a technique for utilising partially corrupt packets. We present an Unequal Error Protection technique that leverages the ability to utilise partially corrupt packets and the nature of the wireless errors to bias the reception of certain portions of the stream.

To overcome the challenges of disconnection due to base station handover or loss of signal, we also consider the benefits of utilising channel diversity and streaming parallel data streams over multiple links. We optimise our UEP subpacket encoding algorithm to leverage the benefits of channel diversity and improve the residual stream quality.

Keywords: GPRS, UMTS, 2.5G, 3G, multimedia, UEP, partial packet corruption

Joint work of: Chesterfield, Julian; Crowcroft, Jon

Disrupted Satellite Networks

Aaron Falk (USC/ISI - Marina del Rey, USA)

Future satellite networks, specifically those for military communications, will be networks which need to tolerate disruption.

For example, a satellite communications network in which one or both of the satellite terminals are on a moving platform, e.g., a truck, will very likely have interrupted communications due to pointing errors due to motion or line-of-sight blocking by buildings, trees, etc. In the worst case, terminals which have connectivity to the satellite as much as 50terminal-to-terminal connectivity may not exist at all. Mechanisms which ameliorate disrupted or disconnected networks will likely be of interest to satellite networks of this nature.

Keywords: Satellite networks disruptive military

Vehicular Ad-Hoc Networks -"Where Disruption is Default and Delay can be Deadly"

Holger Füßler (Universität Mannheim, D)

The talk deals with Vehicular Ad-Hoc Networks in the context of Disruption Tolerant Networking. Vehicular Ad-Hoc Networks (or VANETs) are wireless networks between cars without the assistance of other communication infrastructure than carried on board. The first main thesis is that these networks are disrupted for most of the time. This is due to the fact that at the beginning of deployment only few cars (starting with one) are equipped with the technology. In full deployment, the likelihood of cars blocking each others communications increases. The second main thesis is that 'Delay can be Deadly', i.e. some safety applications are very time criticial and timeliness is crucial.

After having identified this, we formulate the major challenge to design protocols able to deal with that.

Keywords: Vehicular Ad-Hoc NetworksDisruption Tolerance

Towards an experimental test-bed for DTNs

Per Gunningberg (Uppsala University, S)

The Sámi population of Reindeer Herders live in remote areas, and relocate their base in accordance with a yearly cycle dictated by the natural behavior of reindeer. This population currently does not have reliable wired, wireless or satellite communication capabilities in major areas within which they work and live. A radical communication is therefore required. Our proposed SNC (http://www.snc.sapmi.net/) architecture builds on the Delay Tolerant Networking (DTN) technology currently being developed by the Internet Research Task Force - DTN Research Group.

The evaluation of this network will be based on our APE testbed. It is based on an experimental approach to the evaluation of ad hoc routing protocols. We argue that real world experiments are needed in order to complement simulation studies, and to gain practical experience and insights that can provide feedback to routing protocol design and existing simulation models. Experiments with up to 37 participating ad hoc nodes have demonstrated APE's ability to scale efficiently. APE addresses the repeatability issue induced by stochastic factors like the radio environment and node mobility. Using APE, we have performed a systematic experimental evaluation of three ad hoc routing protocols (AODV, OLSR and LUNAR). Our results show that TCP does not work satisfactorily even in very small networks with limited mobility. More information: http://apetestbed.sourceforge.net/ http://www.it.uu.se/research/group/core/

Designing an adaptive routing protocol for delay tolerant ad hoc networking

Stephen Hailes (University College London, GB)

In this talk we presented a stateful protocol for distributing delay tolerant asynchronous traffic in an efficient manner. This was achieved using time series analysis of exchanged context variables based on state space models - actually Kalman filters - to determine which of a range of possible hosts should act as a data mule. To ground this, a mobility model was presented, based on social network theory.

Keywords: DTN, adaptive routing protocol, ad hoc, mobility models

Pocket Switched Networks: Is that a Packet in Your Pocket, or Are You just Pleased to See Me

Ben Hui (Cambridge University, GB)

Opportunistic networks make use of human mobility and local forwarding in order to distribute data. Information can be stored and passed, taking advantage of the device mobility, or forwarded over a wireless link when an appropriate contact is met. Such networks fall into the □ elds of mobile ad-hoc networking and delay-tolerant networking. In order to evaluate forwarding algorithms for these networks, accurate data is needed on the intermittency of connections.

In our work, the inter-contact time between two transmission opportunities is observed empirically using four distinct sets of data, two having been specifically collected for this work, and two provided by other research groups.

We discover that the distribution of inter-contact time follows an approximate power law over a large time range in all data sets. This observation is at odds with the exponential decay expected by many currently used mobility models. We demonstrate that opportunistic transmission schemes deigned around these current models have poor performance under approxmate power-law conditions, but could be significantly improved by using limited redundant transmissions.

Joint work of: Chaintreau, Augustin; Hui, Ben (Pan), Crowcroft, Jon; Diot, Christophe; Gass, Richard; Scott, James

An Architecture for Tetherless Communication

Srinivasan Keshav (University of Waterloo, CDN)

In the emerging paradigm of tetherless computing, client applications running on small, inexpensive, and smart mobile devices maintain opportunistic wireless connectivity with back-end services running on centralized computers, enabling novel classes of applications. These applications require a communications infrastrastructure that is mobility-aware, disconnection-resilient and provides support for an opportunistic style of communiction. It should even be able to function across network partitions that may arise when end-to-end communication is not possible. We outline, design, and evaluate the implementation of an architecture that provides this functionality. we shot that it is possible for next-generation mobile devices to obtain up to 80-fold improvement over conventional mechanisms by exploiting opportunistic WiFi links, and that this benefit can be delivered as an overlay that is compatible with the current Internet.

Keywords: Delay tolerant networks, Opportunistic communication, Tetherless computing, Wireless, Mobile

Joint work of: Seth, Aaditeshwar; Darragh, Patrick; Liang, Suihong; Lin, Yunfeng; Keshav, Srinivasan

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2005/351

Drive-thru Internet: Addressing Disconnection Tolerant Networking Today

Dirk Kutscher (Universität Bremen, D)

Providing Internet Access for Mobile Users that quickly hop from one WLAN access point to another, as pursued by the Drive-thru Internet project, is a special variant of "Disruption Tolerant Networking" that we have named "Disconnection Tolerant Networking". In this paper, we define the term "Disconnection Tolerant Networking" and analyze its specific requirements for network protocols and architecture, as well as for applications and end-system implementations. We examine different solutions and technical building blocks; specifically, we discuss the applicability of the Drive-thru architecture – an intermediary based architecture that provides transport session persistence despite intermittent connectivity. We compare this approach to other mobility management and disruption mitigation oriented efforts and provide some suggestions for future work for an optimized Disconnection Tolerant Networking support.

Keywords: DTN, Disconnection Tolerant Networking, Drive-thru Internet, WLAN, Intermittent Connectivity

Joint work of: Kutscher, Dirk; Ott, Jörg; Bormann, Carsten

Disruption Prediction for Mobile Networks on Public Transport Vehicles

Lavy Libman (National ICT Australia - Sydney, AU)

A research area that has become increasingly important in recent years is that of on-board mobile communication, where users on a vehicle are connected to a local network that attaches to the Internet via a mobile router and a wireless link. In this architecture, link disruptions (e.g. due to signal degradation) may have an immediate impact on a potentially large number of connections. However, when the route is known in advance and repetitive (e.g. for public transport or a regularly commuting private vehicle), a certain degree of _prediction_ of impending link disruptions is possible. In this talk, we present the results of a detailed study of the dependence between the disruption prediction probability and the performance of the TCP protocol, or, more specifically, its extension known as _Freeze-TCP_, using it to demonstrate the significant performance

gains that become possible even with imperfect prediction. We then discuss in detail the architectural issues involved in wireless link disruption prediction and ways it can be harnessed to enhance the performance of network protocols and applications.

Keywords: Mobile networks, public transport, Freeze-TCP, delay-tolerant networking, disruption prediction

Joint work of: Libman, Lavy; Hassan, Mahbub; Baig, Adeel

Towards Protocol Enhancements for Intermittently Connected Hosts

Simon Schütz (NEC Europe - Heidelberg, D)

Internet users are increasingly mobile. Their hosts are often only intermittently connected to the Internet, due to using multiple access networks, gaps in wireless coverage or explicit user choice. When such hosts communicate using the current Internet protocols, intermittent connectivity can significantly decrease performance and even cause connections to fail altogether. This presentation shows experimental measurements of the behavior of Internet communication across a dynamically changing, intermittently connected path. An analysis of the experimental results finds that address changes together with transport-layer timeout and retransmission behaviors are the main limiting factors. Based on these experimental results, we propose a solution that combines the Host Identity Protocol (HIP) with two new protocol enhancements, the TCP Abort Timeout Option and the TCP Retransmission Trigger. Detailed experiments with HIP and a prototype implementation of these protocol enhancements show that they tolerate address changes and arbitrary-length disconnections while significantly increasing performance under intermittent connectivity to about 90

Keywords: Communication system performance, Internet, mobile communication, transport protocols

Joint work of: Schütz, Simon; Eggert, Lars; Schmid, Stefan; Brunner, Marcus

A Pragmatic Approach for "d-burdened" Internet Services

Nils Seifert (Tellitec GmbH, D)

Along an example of an existing and widely deployed Internet via Satellite enhancement software ("TelliNet") the possibilities are shown how to implement services for d-burdened networks (delay and disruption burdened networks) already today.

The talk aims to sensitize the DTN group a bit more not to stop discussion layer 4 implications, but to consider higher layer protocols as well.

Some Thoughts about Security

Hannes Tschofenig (Siemens - München, D)

Some work has been done on DTN security. The currently discussed approaches focus heavily on authentiction using public key cryptography. Unfortunately, the usage of public key crytography has been difficult in large scale deployments (such as the Internet) for end-to-end security and for securing the infrastructure. Authentication itself is insufficient as well.

This talk aims to raise some additional questions regarding authorization.